Patent Citation Flows in R&D Collaborations: The Role of Steering Committees in Managing Misappropriation Concerns in Biotechnology Alliances

ABSTRACT

This research contributes to alliance governance research by demonstrating how and when partners incorporate administrative controls into nonequity collaborations to regulate knowledge transfers across partners. These administrative controls can take the form of board-like joint committees having explicitly delineated authority over certain alliance activities. We illuminate governing committees as an important, albeit neglected, instrument for administrative control in the governance of nonequity alliances, and we demonstrate that these organizational mechanisms facilitate knowledge flows within the scope of an alliance. We also show that governing committees also safeguard against misappropriation hazards, particularly when a partner possesses the incentive and ability to engage in such behavior. This study extends alliance governance research beyond the implications of the equity-nonequity dichotomy to consider a wider and richer gamut of governance instruments available to address the challenges associated with knowledge transfers in alliances.

INTRODUCTION

Firms in high-technology industries require a steady stream of innovations to remain competitive, and innovating successfully often requires firms to update their knowledge bases or bridge gaps in them (Rosenkopf and Almeida, 2003; Rothaermel and Boeker, 2008). Interfirm collaborations offer a key means for firms to access and absorb external knowledge (Hamel, 1991; Kale, Singh, and Perlmutter, 2000) or to assemble the requisite knowledge to develop new products (Shan, Walker and Kogut, 1994; Anand, Oriani and Vassolo, 2010). However, as firms seek to integrate and exploit external knowledge, collaborators also face challenges of transferring and safeguarding valuable and proprietary know-how (Giarratana and Mariani, 2014). Prior research has therefore suggested the need to embed such exchanges in suitable organizational forms (Pisano, 1989; Teece, 1996). Considering the two discrete structural alternatives of equity and non-equity alliances, studies have found that equity arrangements tend to better regulate the knowledge outflows and inflows in alliances (Mowery, Oxley and Silverman, 1996; Gomes-Casseres, Hagedoorn and Jaffe, 2006; Tallman & Phene, 2007).

Given that an increasing amount of collaborative R&D now occurs through contractual, or 'non-equity' alliances (Frankort and Hagedoorn, 2017), a question then arises as to how such challenges are addressed in inter-firm collaborations. In recent research on non-equity alliances, contractual safeguards have been seen as the principal formal governance mechanism at firms' disposal (e.g., Poppo and Zenger, 2002; Anderson and Dekker, 2005), while much less focus has been given to firms' monitoring and control needs that arise when implementing the alliance (e.g., Hoetker and Mellewigt, 2009). The incompleteness of contracts (Williamson, 1985) implies that contracts can only provide a set of safeguards to contingencies foreseen at the start of the trading relationship, so there are bound to be limits on the ability of contractual safeguards to serve the needs of non-equity alliances for coordination and adaptation purposes. Recent research has therefore begun to consider the potential availability or replicability of coordination and control mechanisms similar to those offered by equity forms in contractual alliances (Oxley and Wada, 2009), yet little understanding currently exists about the alternative governance mechanisms that allow partners to manage problems of knowledge sharing and control during the execution of non-equity collaborations. Evidence on partners' usage of contractually-stipulated committees (Robinson and Stuart, 2007), which in some ways resemble boards in equity joint ventures, may provide an important starting point to investigate governance mechanisms in non-equity alliances and examine their implications for the sharing and safeguarding of knowledge in these partnerships.

In this paper, we build upon and extend this emerging stream of research to focus on non-equity alliances' steering committees and examine their effects in facilitating knowledge transfers and mitigating knowledge misappropriation. Specifically, we ask two questions: First, to what extent do steering committees influence knowledge transfers between partners in an alliance? Second, under what conditions do these committees adjust knowledge transfers between partners? Partners delegate authority to these committees in a bounded manner, and they are set up to monitor the progress and performance of an alliance and regulate alliance activities. Such committees are authorized to form and dismiss subcommittees or project teams, to alter the conduct of activities within the scope of the alliance, and to address conflicts between the participants (Smith, 2005). They therefore represent important formal governance mechanisms in non-equity alliances as they allow for joint control and serve an alliance's coordination and oversight needs.

We test our ideas in the context of alliances in the biopharmaceutical industry and use data culled from contracts on non-equity alliances' administrative committees. The industry's knowledge intensity, the long and uncertain product development process, and the upstream and downstream interactions with traditional pharmaceutical companies have motivated many studies to investigate inter-organizational collaborations and their implications in this sector (DeCarolis and Deeds, 1999; Rothaermel and Deeds, 2004). Partners bring proprietary know-how about both technologies and product market applications, thus raising the need to safeguard such knowledge. We focus on the monitoring and control features of administrative structures that can help facilitate and regulate knowledge exchange processes (Heiman and Nickerson, 2004) and can explain how the administrative controls provided by steering committees become particularly important when a partner has a greater ability to appropriate knowledge and a stronger incentive to gain access to proprietary know-how in a collaboration (Sampson, 2004a).

In this paper, we contribute to the alliance literature in two ways. First, we look beyond contractual safeguards to consider committee structures as another formal governance mechanism supporting alliances, one that can have an important bearing on knowledge sharing and safeguarding in partnerships. In so doing, we depart from the prior alliance literature that imputes administrative controls to equity forms alone and thus potentially underestimates the ability of non-equity forms to regulate knowledge transfers between partners. As a corollary, because the administrative controls we examine do not conjointly occur with incentive alignment from shared ownership, as is the case in equity alliances, we are able to isolate the effects of administrative controls on knowledge sharing and safeguarding in interfirm collaboration. Our study suggests that such localized decision-making and control structures instituted specifically for the purpose of the alliance facilitate the coordinated adjustment required for knowledge transfers. Second, our study also unpacks the threats presented by partners' abilities and incentives to appropriate knowledge and shows how they affect knowledge transfers in non-equity alliances. Our findings imply that administrative mechanisms are particularly useful under these conditions. Our study therefore complements prior research on the knowledge transfer implications of different forms of alliances (Mowery *et al*., 1996) by shedding light on the specific conditions under which administrative controls such as steering committees can play an important role in regulating knowledge transfers.

THEORY AND HYPOTHESES

Cooperation in R&D activities raises the hazard of spillover of knowledge to partners who can exploit the spillovers for private gains (Oxley, 1997). Partners confront the challenge of balancing the need to facilitate requisite knowledge exchange in agreed upon areas and limit externalities that arise when cooperating in one line of technological activity that leads to uncovering knowledge in other areas. For meeting this challenge, partners can embed the collaborative activities in a suitable governance structure. Williamson (1991) provides a general framework to understand alternative governance structures by identifying incentives and administrative control as two of the principal dimensions of a governance mechanism. Building on these ideas, research has distinguished equity hybrids from others for the incentive alignment coming from joint ownership and the administrative control coming from a joint board of directors. This research supposes that such joint control mechanisms are unavailable in alliances governed by bilateral contracts (e.g., Oxley 1997; Sampson, 2007).

Nevertheless, partners in non-equity R&D alliances can employ several governance instruments to support their collaboration. Partners not only allocate specific decision rights, or include reporting and auditing requirements in contracts (Lerner and Merges, 1998; Reuer and Ariño, 2007), but also can devise an administrative apparatus that extends beyond procedural control (e.g., Mayer and Argyres, 2004) to expand the adaptive limits of bilateral contracts. Partners can delegate specific authority over monitoring and coordinating the activities of the collaboration to joint administrative structures that are often presumed to be available only to equity alliances. Partners can establish jointly-staffed steering committee that control the activities of the alliance and contractually stipulate the design, functions and performance of these board-like structures (Smith, 2005; Reuer and Devarakonda, 2016). Such committees set up to govern the alliance can be distinguished from *ad hoc* task forces or project teams (e.g., Hoetker and Mellewigt, 2009) based on the contractually defined and enforced scope of decisions and authority. The following excerpt from a contract between Roche and Gilead Sciences signed in 1996 provides an illustration:

> "The Steering Committee shall also monitor the allocation of research and development work between the parties and shall recommend changes as necessary. The parties shall report to the Steering Committee on all significant clinical and regulatory issues relating to Products, and the Steering Committee shall make recommendations and provide strategic guidance with respect to such issues. The Steering Committee shall meet to review and approve a global clinical trial program prior to the conduct of any clinical trials, and shall review and approve the plans for any individual clinical trial of Product in advance of the anticipated commencement date thereof."

These structures can help not only in reducing contracting costs by reducing the need to account for possible contingencies, but also promote efficiency *ex post* by facilitating monitoring and mutual adjustment required for execution of the R&D activities.

We seek to examine the effects of these steering committees on the scope of knowledge transfers occurring between partners in R&D collaborations. Because partners agree to make particular knowledge sets available for meeting alliance objectives, we focus on how partners develop on knowledge relevant to the alliance. The degree to which partners build on each other's knowledge derives from both firm- and dyad-specific characteristics (Mowery *et al*., 1996; Almeida, Song and Grant, 2002; Gomes-Casseres *et al*., 2006). Specifically, partners' ability to absorb and their respective incentives to learn from the other partner can influence the extent of knowledge transfers occurring between them (Sampson, 2004a). Such firm- and dyad-level factors matter because partners remain vigilant to the deep exposure of their knowledge, and the attendant impairment of rent generating abilities in product and intermediate markets. Thus, we wish to consider how steering committees can regulate the build-up of knowledge when enacting the alliance, and intervene to mitigate misappropriation concerns. In the following hypotheses, we first build upon research on alliances and interorganizational learning to suggest that the partner's ability and incentives derived from the value of the focal firm's knowledge will have an impact on knowledge transfers in alliances. After presenting these baseline predictions, we develop the argument that steering committees are able to regulate knowledge spillovers owing to a partner's ability and incentive to engage in opportunistic expropriation of knowledge.

Technology Overlap

One of the main factors driving appropriation concerns in an alliance is the ability of a partner to assimilate any unprotected or proprietary know-how during alliance implementation. For instance, the focal firm may unwittingly divulge proprietary screening techniques or know-how about manufacturing process specifications. The partner can potentially capitalize on such knowledge by employing it for alternative applications or for refining a different set of processes. Following Cohen and Levinthal (1990), research on interorganizational learning argues that firms with the requisite absorptive capacity can benefit from assimilating and productively using the knowledge inflows from external sources (e.g., Zahra and George, 2002).

Prior background knowledge may therefore increase the extent to which a partner can build on focal firm's knowledge by lowering the barriers to assimilate any inflows. The relative knowledge characteristics of the source and the recipient in part determine the efficacy of absorption (Lane and Lubatkin, 1998). Accordingly, the ability of a partner to absorb potential spillovers partly depends on the similarity of the knowledge bases of the partners. Greater similarity between the focal firm and the partner's knowledge bases indicates that the partner possesses prior experience working in technology areas closely related to those of the focal firm (Zander and Kogut, 1995), and familiarity with the structure, content, and utility of the focal firm's knowledge and the potential inflows (Szulanski, 1996). This in turn reduces the ambiguity associated with the knowledge, enabling the partner to better absorb and utilize the focal firm's knowledge (Simonin, 1999). We first offer the following hypothesis on partners' ability to appropriate knowledge as a baseline prediction:

> *Hypothesis 1: The degree to which partners build upon each other's knowledge is positively associated with the technology overlap between the partners.*

Value of a Firm's Knowledge

While the foregoing discussion emphasizes the ability of a partner to absorb and build on the knowledge of its counterpart, partners will also differ in their incentives to actively internalize a partner's knowledge (Hamel, Doz and Prahalad, 1989; Kale *et al.,* 2000). Alliances allow exposure to a partner's proprietary skills, routines, and know-how and create new technological opportunities by combining these spillovers with existing knowledge. The opportunities that open up, and hence the incentives to actively internalize a partner's knowledge, are not uniform, but vary significantly across partners and collaborative agreements. As the intrinsic value of a firm's knowledge increases, the opportunities created for a partner upon absorbing any spillovers, and thus the private benefits of collaboration, become more valuable for the partner (Khanna, Gulati and Nohria, 1998).

The incentive to appropriate valuable knowledge from the firm also gets impacted by the cost of actions for assimilating the knowledge, which come in several forms. To begin with, firms need to allocate resources to the collaboration and other projects. As one example, firms may have to hire or deploy human resources with the necessary skills (Gersbach and Schmutzler, 2004). Firms may have to redeploy productive employees from other projects to the focal alliance, thus creating a cost of foregone opportunity by way of loss in productivity in the original projects. Alternatively, firms may have to incur search and deployment costs of hiring employees from the labor market. Firms may also have to offer incentives to employees in order to facilitate the adoption of incoming spillovers (Dearden, Ickes and Samuelson, 1990). In addition, the firm may also alter its monitoring of agents tasked with learning about and adapting the incoming spillovers. Inasmuch as it is costly to adjust the organization of these activities within a firm (e.g., Cooper and Haltiwanger, 2006), then it is more likely that a partner will seek to internalize and build upon the firm's knowledge as the value of the firm's knowledge increases. Before elaborating on whether steering committees can mitigate knowledge appropriation, we offer the following hypothesis on partners' incentives to appropriate knowledge as a baseline prediction:

Hypothesis 2: The degree to which partners build upon each other's knowledge is positively associated with the value of the partners' knowledge.

Steering Committees

In a basic model of knowledge transfer between partners, the previous two hypotheses suggest determinants of the extent of knowledge flows based on characteristics of the originator and the beneficiary of the knowledge. In this sense, these two factors support and encourage inter-partner learning independent of the managerial structure that is embedded in the alliance agreement. We now consider the organizing mechanisms of the alliance that shape the mutual build-up of knowledge by enabling partners to address challenges posed by the inherent knowledge characteristics and the nature of tasks involved in knowledge production.

The relevant knowledge that is required to meet alliance goals exists in both explicit and tacit form. Partners can learn about ideas, techniques and processes that compose each other's knowledge base by examining the corresponding patent documents and scientific publications (Mansfield, 1985; Merges, 1988). However, knowledge already codified in these forms can only partially provide the input required for productively pursuing the new ideas on which partners intend to collaborate (Ouellette, 2012). When innovation proceeds as a trial and error process, the knowledge base is experience based and exists in tacit form (Arora, 1995). Thus, partners also generally need to obtain necessary inputs from partners, and this knowledge is often sticky and presents difficulties in transfer (Szulanski, 1996). During the process of knowledge sharing, partners may also have to engage in joint problem solving, which requires effective management of the interactions between personnel, and directing the associated search processes (Nickerson and Zenger, 2004). Committees governing the alliance can serve as useful interfaces that enable partners to overcome the challenges involved in coordinating their activities.

Contractually designed steering committees come with several attractive features that allow them to effectively guide knowledge exchange in these ways in alliances. These jointly staffed committees can use their authority over activities that fall within the scope of the alliance to establish and formalize communication channels that structure the interaction between partners for alliance-related activities. They can further enhance the efficiency of communication by adopting codes that are mutually agreed upon and are adopted by the partners. They are empowered to determine the division of tasks among project teams, regularly review their progress, and adjudicate on any disputes that arise in such teams. Committee also serves as the bilateral reference forum to turn to in the event of any unforeseen contingency when conducting R&D tasks through successive stages. In sum, the joint committee that partners engineer during contracting serves to centralize the oversight and management of alliance activities. Therefore, we propose the following hypothesis on the steering committee's ability to effectively guide knowledge exchange in alliances:

> *Hypothesis 3: The extent to which partners build upon each other's knowledge is positively associated with the presence of a steering committee.*

Moderating Effects of Steering Committees

While the foregoing discussion conveys the usefulness of steering committees in addressing challenges associated with knowledge transfer in general, steering committees can also specifically reduce the hazards associated with knowledge misappropriation that can follow from an individual partner's likelihood of engaging in such opportunism. More specifically, in our first two baseline hypotheses, we identified two main antecedent conditions that can potentially increase the threat of knowledge appropriation, so we expect that steering committees will address these two root sources of *ex post* exchange hazards in R&D collaborations.

Firms can employ several protection mechanisms to safeguard their intellectual property.

In general, firms can rely on patents, copyrights and trade secrets to protect critical information (Cohen et al., 2000). However, these mechanisms are limited in their ability to safeguard valuable knowledge resources because not all knowledge residing within a firm is eligible for such legal protection. Specific to an individual alliance, firms can also stipulate contractual safeguards to delineate what knowledge is shared between the partners, and what rights partners have over the shared knowledge, and how such shared knowledge may be applied in the future. Thus, the general intellectual property rights mechanisms combined with the alliance-specific contractual safeguards provide a legal basis for the firms to collaborate in an alliance. However, contractual safeguards are also limited in protecting against risks that befall the firm during the implementation of the alliance, and know-how or valuable ideas that are not legally protected are particularly at risk. In this respect, administrative structures that oversee the knowledge contributed by partners become an important part of the governance design of R&D alliances.

Valuable knowledge can be appropriated within an R&D alliance by several means. Alliances can open private channels of interaction such as email and IT tools that may provide contact to the critical resources within the firm (Appleyard, 1996). This private access combined with increased transparency of knowledge obtained through the alliance creates points of contact between the partnering firms where critical know-how can be exposed (Heiman and Nickerson, 2004; Giarratana and Mariani, 2014). When left without adequate controls, a decentralized way of functioning in non-equity alliances can result in unwarranted access to the organizational contexts within which exchange of tacit knowledge takes place within organizations (Sampson, 2006; Heiman & Nickerson, 2002). Scientists and researchers may be less cognizant of misappropriation concerns and may discuss and reveal valuable incipient ideas gained through experience. Documents such as test data or blue prints are also at the risk of being inadvertently shared with the partner. In particular, in the biotechnology sector test data about molecules and how the molecules function are critical, so loss of such non-patentable data and information to a partner may severely hamper the firm's ability to extract future rents (Pisano, 2006). As we have discussed in developing our baseline hypotheses (H1 and H2), the potential loss of knowledge through these various means can increase significantly when the firm possesses valuable know-how or when the partner has the requisite abilities and complementary capabilities and know-how to take advantage of the spillovers.

Administrative structures in the form of steering committees can help partners mitigate these concerns in several ways. Steering committees with oversight responsibilities for the alliance can serve as a screen for the knowledge processes between partners. The joint decision-making processes driven by consensus can also safeguard the interests of each of the partners. These characteristics of steering committees not only can reduce the risk of appropriation in the first place but enable the partners to selectively intervene in the alliance as and when a threat is detected. Steering committees thus serve as potent monitoring instruments to tackle the threat of leakage of intellectual property and preserve the value of their knowledge assets.

Steering committees can therefore mitigate knowledge transfers tied to a partner's ability and incentives to appropriate knowledge discussed earlier, for several reasons. First, this structure overlays a formal administrative layer on top of the technical or operational management of an alliance. The steering committee by itself or through appointed subcommittees can structure the interactions of researchers and reduce the need for direct interactions between many scientists and technical personnel. Second, by using its delegated authority, the committee can formulate rules of engagement and interaction between the partners' employees (Liebeskind, 1997). In this way, the partners can regulate access to critical human resources. The steering committee can also suitably manage the extent of socialization and face-to-face contact between individuals in order to limit the transparency of knowledge (Heiman and Nickerson, 2004). Finally, the steering committee can not only institute rules governing partners' interactions but also monitor their implementation.

In a similar fashion, the steering committee can also facilitate monitoring of resource allocation decisions of the partners. For instance, when the focal firm has valuable knowledge, this can induce the partner to devote greater resources to value appropriation, as described above (Diestre and Rajagopalan, 2012). By detecting opportunistic deployment of resources or unauthorized leakage, the firm can appropriately respond either through legal means or through termination if adjustments to the collaboration orchestrated by the steering committee are not adequate. We therefore posit that steering committees can mitigate appropriation problems that arise when a partner has a greater ability or incentive to appropriate a firm's knowledge:

> *Hypothesis 4: The presence of a steering committee reduces the positive effect of technology overlap on the extent to which the counterpart builds on a partner's knowledge.*

> *Hypothesis 5: The presence of steering committee reduces the positive effect of the value of partner's knowledge on the extent to which the counterpart builds on a partner's knowledge.*

METHODS

Data for our empirical analyses come from several sources. We use pooled cross sectional data from alliances in the biopharmaceutical industry. This sector serves our purposes well because pharmaceutical firms increasingly rely on collaborations for innovation

(Hagedoorn, 2002). Our analysis suggests that recent investments in collaborative R&D arrangements have been in range of USD 15 to 40 billion per annum. Anecdotal evidence from our conversations with managers involved at major pharmaceutical companies such as Eli Lilly and Johnson and Johnson have revealed that each collaboration is idiosyncratic and managers design them with great care. From this perspective, a key benefit of studying collaborations in this sector is to reveal systematic regularities that accord with theoretical principles that would inform the design of collaborations in other high tech sectors as well. Moreover, the sector prominently utilizes patents as the chief appropriation mechanism (Arora, Ceccagnoli and Cohen, 2008), allowing the use of patent data to assess various knowledge characteristics of the partners. We combine information from alliance contracts available from Thomson Reuters' Recap database (e.g., Schilling, 2009), and we augment these data with information from the alliances module of Thomson Financial's Securities Data Corporation (SDC) database in order to track prior alliances. We also match these data with patent data from PATSTAT, the worldwide patent database compiled by the European Patent Office (EPO).

We consider non-equity R&D alliances formed in the period 1987-2006 between a pharmaceutical and a biotechnology firm or between two biotechnology firms. Because we analyze knowledge transfers, we focus on alliances that aim to conduct R&D in order develop products for therapeutic applications and involve a non-trivial knowledge component, and we exclude other types of interfirm agreements. Further, we concentrate on alliances which involve knowledge exchange and for which we can extract information about contractually defined administrative controls. We rely on Recap's catalogue of the alliances to identify agreements classified as Research, Development, Co-Development, and Collaboration, and for which Recap provides a contract and its analysis. To enable construction of patent-based measures, we also focus on alliances wherein both partners have applied for a patent with a patent issuing organization (e.g., USPTO, EPO etc.). After accounting for outliers, these steps yielded a final sample of 350 non-equity alliances.

Measures

Dependent Variables. A substantial body of research in economics and business has used patent citations as indicators of knowledge flows (e.g., Jaffe, Trajtenberg and Henderson, 1993; Almeida, 1996). Evidence from surveys supports the notion that patent citations trace the paths of knowledge acquisition by firms (Duguet and MacGarvie, 2005). We follow this literature and use patent citations to gauge knowledge transfers between partners (e.g., Rosenkopf and Almeida, 2003). We are mainly interested in the extent to which partners build on each other's knowledge post-formation, and measure this as the number of times partners cite each other *ex post* while excluding citations that originated during patent examination.

We are specifically interested in measuring knowledge transfers related to the scope of the alliance. The challenge here is to link the knowledge domain of the alliance to a related set of patent classes. For developing this concordance, we use Recap's assignment of each alliance to specific technology areas drawn from a catalogue containing over 50 types of technologies (e.g., recombinant DNA, monoclonal antibodies, immunoglobulins, etc.). We match these areas to specific technology groups under the Cooperative Patent Classification (CPC) scheme (CPC, 2016). Based on CPC-defined technology groups (the nested levels are: section, class, subclass, group, and so on.), we identify patents and citations that belong to technologies related to the alliance, and determine knowledge flows that fall within and outside the scope of the alliance.

Our primary dependent variable therefore counts the number of times within a given time window after alliance formation a partner cites any of its counterpart's patents that belong to the technology domain of the alliance. Because partners are more likely to cite each other in the five year window after formation (Gomes-Casseres *et al.*, 2006), we follow previous research and employ a 5 year window and use a 7 year window as a robustness check. We distinguish partners as the R&D Firm and Client Firm based on which partner primarily contributes technology to the alliance, as indicated by Recap. Separately considering the knowledge build-up by each of the partners allows us to incorporate this asymmetry in knowledge contribution to the alliance. Thus, our measures account for both the direction and the extent of knowledge transfer between the partners (Oxley and Wada, 2009). *Citations by client firm*, counts the number of times the client firm's patents cite the R&D firm's patents. Similarly, *Citations by R&D firm*, counts the number of times the R&D firm's patents cite the client firm's patents.

Independent Variables. Our first explanatory variable is a measure of the firms' technology overlap and quantifies how close the partners are in technology space. We use the method Jaffe (1986) proposed to calculate this measure, relying upon the distribution across CPC technology groups of all patents applied for prior to the alliance formation to derive a patent vector for each partner. We then calculate *Technology overlap* between the partners as the uncentered correlation coefficient, which is bounded by 0 and 1 and takes greater values when the technology profiles of the partners become more congruent (Oxley and Sampson, 2004).

Our second explanatory variable is a partner-specific measure of the value of technological resources, which we build for the partner's patent portfolio. Prior research has shown that forward citations received by a patent serve as a key indicator for their value (Hall, Jaffe and Trajtenberg, 2005). In order to capture the value of patents in technological areas that are focal to the alliance, we followed the approach we employed for capturing patent cross citations. Taking into account all issued patents applied for in a 10-year window prior to the alliance, we counted the number of forward citations received in the 5-year window after the grant (Mehta, Rysman and Simcoe, 2010) and apply a logarithmic transformation. We construct two sets of variables for knowledge within and outside the scope of the alliance, which we label *R&D firm knowledge value (in scope), Client firm knowledge value (in scope),* respectively, for the value of the R&D and client firms' knowledge within the scope of the alliance, and *R&D firm knowledge value (ex scope), Client firm knowledge value (ex scope),* respectively, for the value of their knowledge outside the scope of the alliance.

Our third explanatory variable is the *Steering committee* indicator. We refer to the alliance contract to identify whether the alliance partners establish a joint steering committee with oversight responsibilities of alliance activities. Thus, *Steering committee* is a binary variable which equals one when such steering committee exists and zero otherwise. Because the decision to establish a steering committee is unlikely to be random, we first estimate the probability of the partners establishing a steering committee to oversee the alliance. For this purpose, we draw on recent research that suggests that moral hazard, misappropriation, and coordination challenges drive the choice of the governance structures that support alliance activities (Pisano, 1989; Oxley, 1997; Gulati and Singh, 1998). Accordingly, steering committees may be set up to monitor potential misappropriation arising from high overlap in partners' knowledge bases (Oxley and Sampson, 2004), to monitor moral hazard concerns arising from the size and complexity of the alliance (Coles, Daniel and Naveen, 2008), and to coordinate interdependent activities between the partners (Gulati and Singh, 1998). We use *Technology overlap* as described above to proxy for the overlap in knowledge bases of the partners. We use the potential monetary value of the alliance between partners as *Deal size* to proxy for the transaction's complexity, using data from Recap. Based on this dataset's description of the division of alliance-related labor between the partners, we code collaborations according to their *Reciprocal interdependence*, where deals categorized as "Collaboration" or "Co-Development" are considered reciprocal (Gulati and Singh, 1998). In addition to these key determinants, we also include several alliance and partner level variables which we describe in the following section. In the Analyses subsection below, we describe how we use the estimated propensity of firms to use steering committees in our models of knowledge flows between partners.

Control Variables. We control for several features of the partners that may potentially explain the observed level of partners' cross-citations following alliance formation and also might be related to the independent variables described above. To begin with, cross-citations may follow naturally from an ongoing technical relation between the firms' knowledge bases. To control for this, we count the number of times partners cite their counterpart's patents prior to the alliance and take a logarithm of this value to compute *Pre-Alliance citations by R&D firm* and *Pre-Alliance citations by client firm* (Oxley and Wada, 2009). We also include the Herfindahl index of the concentration of partners' patent portfolios in the primary patent classes (Oxley and Wada, 2009) to control for specialization of knowledge, which we label *Concentration of R&D firm knowledge* and *Concentration of client firm knowledge*. The post alliance citation level may also ensue from the learning acquired from previous alliances with other organizations (Anand and Khanna, 2000). We count the number of alliances the partners formed before the focal alliance (Hoang and Rothaermel, 2005) and use a logarithmic transformation to calculate the *Alliance experience of R&D firm* and *Alliance experience of client firm*.

We also control for several features of the alliance that may affect the observed level of partners' cross-citations. We control for the effect of the size of the collaboration by including *Deal size*, defined as the maximum possible payments through the life of the partnership agreement (Robinson and Stuart, 2007). Partners may also employ complex contracts to safeguard their knowledge assets. Therefore, we include *Contract complexity* as the logarithm of the byte size of the standard contract analysis provided by Recap (Robinson and Stuart, 2007). We also control for incentive alignment between partners achieved through contingent payment structures incorporated in the contract. We measure *Incentives* as an indicator variable for the inclusion of contingent payments in the alliance. In addition, prior relationships between partners may either initiate follow-on knowledge exchanges or serve as relational governance mechanisms to mitigate appropriation. We therefore include the *Prior ties* (Gulati *et al*., 2009) as the number prior alliances between the partners that precede the focal alliance. We also control for whether the alliance is between partners from different countries (*International alliance*), using a dummy variable that equals one if the partners' headquarters are located in different nations (Gulati, 1995), and zero otherwise.

We also control for several features of the alliance to control for unobserved factors that may influence knowledge transfers. We include the dummy variable *Biotech-Biotech Deal* that equals 1 if both the partners are classified as biotech firms, and 0 for alliances between biotech and pharmaceutical firms (Lerner *et al*., 2003). Finally, we incorporate *Phase fixed effects* to control for the stage of the alliance in the drug development cycle and *Period fixed effects* to control for changes in citation patterns over time (Hall *et al*., 2001).

Analyses

Our analysis aims to estimate the effect of steering committees on the intensity of partners' cross-citations after an alliance is formed. In pursuing such an objective in a nonexperimental setup, the principal concern is the bias associated with the selection of observed units into different policy regimes or treatments. In order to address this bias and recover the average effect of steering committees, we follow the precedent of several empirical studies in economics and employ the propensity score matching technique (Dehejia and Wahba, 2002). This method assumes that matching treated and untreated units on observed factors also balances them on the unobserved factors, thus allowing identification of the treatment effect. To model the selection of steering committee, we use a rich set of covariates at both partner and alliance level that extant literature has shown to determine governance choice in alliances, as described above. The specific method we implement follows Hirano and Imbens (2001) and combines propensity scores with regression. In this method, the bias can be removed by first estimating the propensity score, and then weighting observations with the inverse of the propensity to receive the observed treatment to estimate a weighted regression model (Hirano et al., 2003). We estimate the propensity score using a probit model (see Azoulay et al. (2009)).

We then employ a negative binomial framework for our regression of knowledge transfers across partners because of the count nature and over dispersion of citations. The dispersion parameter (α) is significant ($p<0.001$) in all our models, thus confirming over dispersion in the data and supporting the selection of a negative binomial framework. We report heteroskedasticity-robust standard errors. Because several client firms in our final sample enter into more than one alliance, we report standard errors clustered on the client firms.

Insert Table 1 here

Descriptive statistics and correlations appear in Table 1. Of the 350 alliances in our sample, 35 percent utilize a steering committee to oversee the alliance. As might be expected, the R&D firm's patent stock tends to be more concentrated (p<0.001), and client firms' patents tend to be more frequently cited (p<0.001). Partners more intensely cite each other post alliance than pre-alliance (p<0.001). We examine variance inflation factors (VIF) to diagnose multicollinearity concerns and find that the maximum VIF is 2.4, which is well below the critical value of ten.

In Table 2, we report estimates of a probit model for propensity scores for steering committees. These findings confirm that firms tend to put in place steering committees when faced with *ex post* exchange hazards and coordination needs for their collaborative agreements. Specifically, estimation results indicate that steering committees are more likely when firms face higher levels of technology overlap (p=0.043), and form a larger collaboration (p<0.001). The coefficient estimate for reciprocal interdependence is also positive (p<0.001). Using this specification, we estimate the probability of establishing a steering committee for each observation. We then calculate the weights using the following formula:

$$weight_i = \frac{I(Steeringcommittee_i = 1)}{\hat{p}_i(Steeringcommittee = 1)} + \frac{I(Steeringcommittee_i = 0)}{1 - \hat{p}_i(Steeringcommittee = 1)}$$

where *I* is an indicator function for whether partners establish a steering committee or not and p-hat is the estimated likelihood of a steering committee being present. We also performed additional checks to investigate potential concerns arising from the use of weights from propensity scores (results available from the authors). First, when using matching estimators such as ours, a potential bias exists when there is no common support between the treated and the control samples (Heckman *et al*., 1997). We therefore constructed density plots of the propensity scores, which demonstrate that a comparison group exists for almost all treated group observations across the range of propensity scores, thereby alleviating the common support concern (Heckman *et al*., 1996). Second, we repeated our analyses presented below by excluding observations with the extreme values of propensity scores where and imbalance between treated and control groups is more likely and found consistent results.

Insert Table 2 here

We present two sets of results that separately analyze the knowledge transfers to each of the partners to test our hypotheses. Table 3 shows estimates of negative binomial regression models where the dependent variable is *Citations by client firm*. Table 4 shows estimates of binomial regression models where the dependent variable is *Citations by R&D firm*. In these tables, we report estimates of the baseline regression in model 1. In model 2, we introduce the main effect of steering committee. Models 3 and 4 successively introduce the individual interaction effects with technology overlap and the partner's knowledge value. Finally, model 5 includes the full set of interactions.

Insert Table 3 & Table 4 here

In the baseline models, we examine how ability of a partner to appropriate knowledge as well as the value of the focal firm's knowledge affect knowledge build-up by the partner in a five year window after the formation of the alliance. Hypothesis 1 suggests a positive sign for the coefficient of *Technology overlap* in both tables. In Table 3, we find that the estimated coefficient of *Technology overlap* is positive (p=0.036), which can be interpreted in semielasticity terms as an 45% increase in citations by a client firm from the mean for a one standard deviation increase in *Technology overlap*. Hypothesis 2 suggests a positive sign for the coefficient of *R&D knowledge value (in scope)* in Table 3 and a positive coefficient for *Client firm knowledge value (in scope)* in Table 4. We find that the estimated coefficient of *R&D firm knowledge value* is positive (p<0.001), as is the estimated coefficient of *Client firm knowledge value* in column (1) of Table 4 (p<0.001). A one percent increase in *R&D knowledge value* increases the citations of the R&D firm's patents by the client firm by 1.96% (p<0.001), and a one percent increase in *Client firm knowledge value* increases the citations of the R&D firm's patents by the client firm by 2.08% (p<0.001) with all other variables held constant. These baseline regression results support our argument that greater ability of the partner by way of absorptive capacity, and greater incentives owing to the focal firm's knowledge value, increase the intensity of knowledge build-up by the partner.

Turning to the main effects of steering committees, column (2) in Tables 3 and 4 shows the impact of having a steering committee on the citations by the client firm and the R&D firm, respectively. Consistent with our third hypothesis, the estimated coefficient of *Steering committee* in column (2) of Table 3 is positive (p=0.032); when partners establish a steering committee the intensity with which the client firm cites the patents of the R&D firm increases by the client firm on average increases by 95 percent. Similarly, the estimated coefficient of *Steering committee* in column (2) of Table 4 is positive (p=0.084); when partners establish a steering committee the intensity with which the R&D firm cites the patents of the client firm increases by 59 percent. These results imply that steering committees support knowledge transfers between partners in areas that fall within the scope of the alliance.

We next investigate the effects of steering committees when partners face appropriation threats originating from a partner's ability and incentive to appropriate knowledge. To the extent that the partner's ability (H4) and incentives (H5) to misappropriate knowledge make it more likely for this problem to be manifest in a collaboration, the presence of a steering committee overseeing the collaborative activities should mitigate the adverse effects of technology overlap and partner knowledge value, respectively. Hypothesis 4 suggested that the effect of *Technology overlap* on citations by the partner firm will diminish for collaborations utilizing steering committees. Accordingly, we anticipate a negative sign for the interaction between *Steering committee* and *Technology overlap* in models shown in column (3) of Tables 3 and 4. As expected, we find that the estimated coefficient of this interaction term is negative (p=0.05) in column (3) of Table 3. In column (3) of Table 4, although the sign of the interaction term in the anticipated direction, it is not significant at conventional levels (p=0.34). These results suggest that the steering committees act on the threat of increased knowledge transfers from the R&D firm as the overlap increases.

Finally, we test the interaction between steering committees and partners' knowledge value in column (4). In hypothesis 5, we propose that steering committees can mitigate the effects of a partner's incentive to appropriate when the firm has valuable knowledge. This suggests a negative sign for the interaction term between *Steering committee* and *R&D (or Client) firm knowledge value* in Table 3 and 4. We find that the estimated coefficient of the interaction between *Steering committee* and *R&D firm knowledge value* in column (4) of Table 4 is negative (p<0.001). We also find that the estimated coefficient of the interaction between *Steering committee* and *Client knowledge value* in column (4) of Table 4 is negative though only of marginal significance (p=0.097). These results suggest that steering committees tend to regulate knowledge flows in response to the incentive to appropriate. Moreover, our results imply that the function of steering committees in safeguarding valuable knowledge applies more strongly for R&D firms, which are the primary contributors of technology to an alliance.

To further clarify the moderating effects of steering committees, we graphically depict key interactions in Figures 1, 2 and 3. The expectation function in a negative binomial framework is linear on logarithmic scale, which we use in the figures. Figure 1 uses the estimation results from column (3) in Table 3 and depicts the impact of steering committees on the relationship between overlap in technologies and knowledge transfer from the R&D firm to the client firm for an alliance signed in 2000 in the oncology area with no citations prior to the alliance, and with all other variables maintained at sample averages. Figure one shows two graphs: the graph labeled as *Steering committee*=1 traces the log of the mean of the cross citations when a steering committee is present to oversee the alliance; the graph labeled as *Steering committee*=0 traces the log of the mean of the cross citations when a steering committee is not present. The effects accord with the argument that steering committees attend to the risk of knowledge leakage arising from greater overlap in partners' knowledge.

Insert Figures 1, 2 and 3 here

Moving to the interaction between steering committee and partners’ knowledge value, Figures 2 presents interaction plots by depicting the impact of steering committees on the relationship between the knowledge value of the R&D firm and knowledge transfers from the R&D firm to the client firm for an alliance signed in 2000 in the oncology area with no citations prior to the alliance and with all other variables maintained at the sample averages; Figure 3 does the same for the relationship between knowledge value of the client firm and knowledge transfers from client firm to the R&D firm. The less pronounced effects of knowledge value on knowledge transfer in the presence of steering committees is consistent with the theoretical argument that such committees attend to appropriation concerns in alliances.

Additional analyses

We performed a variety of tests to confirm the effects of steering committees on the knowledge transfers between partners. Up to now we have considered the cross patent citations between partners in the technology areas that are closely related to the alliance. We also considered the effects of steering committees on knowledge transfers in areas that are unrelated to the technologies that are focal to the alliance. For this purpose we constructed two dependent variables that measure the number of times partner cites the patents of their counterpart which do not belong to the technology groups that correspond to the alliance. We summarize some of the noteworthy results (results available from the authors upon request). To begin with, the coefficient of *Technology overlap* is positive and significant ($p<0.001$) in specifications for citations to the R&D firm's patents by the client firm. This finding suggests that the absorptive capacity of the client firm enables it to learn from the R&D firm in areas outside the scope of the alliance. However, a similar effect is not found in the case of the transfers from the client firm to the R&D firm. We also find that the coefficient of *Steering committee* is not significant for knowledge transfers outside the scope of the alliance, nor are there significant interactions.

Taken together, our findings suggest that the presence of a steering committee in the governance structure of the alliance is robustly correlated with regulating knowledge transfers in alliances faced with greater misappropriation concerns, especially for the R&D firms, which are the main suppliers of technology. We find these results to be consistent with the fact that technology contributions to the alliance are not symmetric and client firms play a secondary role in that respect. Owing to the greater risk of appropriation that R&D firms may face, they are apt to safeguard their knowledge assets more intensely than client firms.

DISCUSSION

Contributions and Implications

Our paper examines the effect of committees governing non-equity alliances on the knowledge transfers that occur between partners in R&D alliances. Previous alliance research has emphasized greater incentive alignment and hierarchical control for confronting appropriation challenges, and this literature mainly associates these two instruments with the joint ownership and the administrative apparatus present in equity alliances. This research has developed assuming that administrative control mechanisms are generally lacking in contractual alliances, thus making difficult the coordinated adjustment and monitoring required for effective knowledge transfer (e.g., Sampson, 2007). We suggest that governing committees entail delegated authority offer important control mechanisms in contractual alliances, and we also help to illuminate their effect on knowledge transfers. Specifically, we elucidate the conditions that accentuate the effect of the control exercised through governing committees in alleviating knowledge appropriation concerns in R&D alliances.

Our study sheds light on some key aspects of the design of contractual alliances. By paying attention to steering committees, our study illustrates the ramifications of the structural planning dimension of contract design. Specifically, we show the effects of the administrative apparatus that partners incorporate in the contract to address the problem of knowledge sharing and misappropriation, which can arise as partners undertake joint activities over a longer period of time (Palay, 1983; Williamson, 1991). Our study implies that steering committees with explicitly delegated authority can guide the partners' interactions and intervene as necessary to appropriately adapt and facilitate knowledge transfer. By analyzing the adaptation effects of these committees in promoting knowledge flows within the scope of the alliance, we sharply focus on the consequences of the design of administrative control instruments in collaborations (Mayer, 2006; Sampson, 2007). Thus, the study not only corroborates some of the conclusions of previous studies derived from the study of equity alliances, for which control mechanisms conjoin incentives, but the study also uniquely underscores the effect of administrative control instruments (Oxley, 1997; Heiman and Nickerson, 2004; Oxley and Wada, 2009).

Our study also elaborates upon the contingent effects of steering committees on knowledge flows. Our analyses indicates that steering committees respond to potential threats of excessive exposure of knowledge resulting in erosion of value when partners have the ability and incentives to engage in opportunistic behavior. Our results therefore suggest that the protective, monitoring role of steering committees intensifies as the threat of self-interested behavior from partners in the R&D activities alliance escalates. Our results therefore shed light on the dedicated structures through which partners manage alliance activities and monitor partner actions to prevent, detect, and respond to unexpected spillovers (Kale *et al*., 2000).

Limitations and Future Research

Our study also have a number of limitations that extensions might pursue in future research. First, our study deals with alliances in the biotechnology sector, in which a strong appropriation regime incentivizes firms to actively engage in patenting, and the complementarity of R&D resources and capabilities drives collaborative activity. These characteristics features of this sector induce the use of sophisticated governance mechanisms. It would therefore be useful to study the effects of alliance structuring and contractually delegated authority in other industry settings and for different types of collaborations and stages of the value chain to investigate the generalizability of our findings.

By considering the design of committees at the beginning of the alliance, our study does not consider the dynamic effects of these committees. In this sense, we are not able to unpack whether the steering committee actually addresses incipient misappropriation of knowledge to reduce it once it is manifest, or whether the presence of this governance mechanism reduces the likelihood that misappropriation emerges in the first place. Future research might also investigate the individuals involved in the committee as well as others in the alliance to determine more precisely how knowledge flows are controlled and how partners may choose to empower the committees with greater authority over alliance activities when leakages are detected, or redesign committee structures. Future research might also investigate conditions under which their misappropriation might escape the committee's detection and be addressed by other means.

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Table 1: Descriptive statistics and correlation table

	Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	Citations by client firm (in scope)	1																					
2	Citations by R&D firm (in scope)	0.04	1																				
3	Citations by client firm (ex scope)	0.37	0.51	1																			
4	Citations by R&D firm (ex scope)	0.06	0.70	0.54	1																		
5	Steering committee	0.09	0.03	0.09	0.06	1																	
6	Technology overlap	0.12	0.22	0.23	0.25	0.19	1																
7	R&D firm know. value (in scope)	0.19	0.14	0.15	0.12	0.2	0.28	1															
8	Client firm know. value (in scope)	0.19	0.19	0.21	0.24	0.09	0.39	0.03	1														
9	R&D firm know. value	0.14	0.16	0.24	0.21	0.27	0.31	0.79	0	1													
10	Client firm know. value	0.14	0.16	0.24	0.21	0.27	0.31	0.79	0	1	1												
11	Conc. Of R&D firm knowledge	-0.05	-0.09	-0.12	-0.12	-0.14	-0.03	-0.23	-0.01	-0.42	-0.42	1											
12	Conc. Of client firm knowledge	-0.06	-0.06	-0.10	-0.11	-0.03	-0.11	0.00	-0.38	0.02	0.02	-0.13	1										
13	Alliance exp – R&D firm	-0.02	0.04	0.02	0.06	0.14	0.03	0.28	-0.06	0.38	0.38	-0.23	0.12	1									
14	Alliance exp – client firm	0.16	0.13	0.22	0.18	0.10	0.16	0.04	0.43	0.04	0.04	0.00	-0.34	-0.07	1								
15	Pre-alliance citations by client firm	0.43	0.50	0.72	0.38	0.08	0.18	0.19	0.19	0.21	0.21	-0.1	-0.06	0.03	0.2	1							
16	Pre-alliance citations by R&D firm	0.05	0.82	0.46	0.71	0.07	0.28	0.11	0.19	0.16	0.16	-0.04	-0.08	0.01	0.16	0.53	1						
17	Deal size	0.07	0.19	0.19	0.26	0.31	0.29	0.16	0.34	0.2	0.20	-0.12	-0.26	-0.03	0.35	0.23	0.24	1					
18	Contract complexity	0.12	0.12	0.11	0.14	0.33	0.17	0.06	0.16	0.07	0.07	-0.09	-0.12	0.05	0.21	0.1	0.14	0.45	1				
19	Incentives	0.01	0.06	0.04	0.1	0.08	0.1	0.06	0.06	0.05	0.05	0.00	-0.13	-0.09	0.12	0.07	0.1	0.52	0.23	1			
20	Prior ties	0.06	-0.04	-0.03	0.00	0.06	-0.08	-0.1	0.07	-0.11	-0.11	0.04	-0.08	0.04	0.15	-0.02	0.02	-0.01	0.09	-0.06	1		
21	International deal	0.08	0.02	0.00	-0.02	0.09	0.03	0.07	-0.06	0.05	0.05	-0.08	-0.02	-0.04	-0.13	0.02	0.02	-0.04	-0.08	-0.02	-0.04	1	
22	Biotech-biotech deal	-0.05	-0.06	-0.11	-0.1	-0.04	0.09	-0.03	-0.19	-0.07	-0.07	-0.06	0.35	-0.07	-0.25	-0.05	-0.08	-0.13	-0.03	-0.05	-0.1	-0.22	1
	Mean	1.49	2.85	2.31	4.62	0.35	0.22	277.69	1008.3	1010.0	8036.7	0.17	0.06	11.87	44.85	0.61	2.15	73.49	22.63	0.68	0.15	0.46	0.19
	S.D.	7.98	18.75	8.84	18.21	0.48	0.22	709.89	1892.0	2911.0	11760.2	0.15	0.10	15.57	42.65	3.88	11.98	138.03	10.52	0.47	0.42	0.50	0.39

N=350. Values > 0.10 are significant at $p<0.05$

Table 2: Determinant of steering committees

Variables	(1)
Technology overlap	0.198*
	(0.098)
Reciprocal interdependence	0.743***
	(0.174)
Deal size	0.430***
	(0.116)
R&D knowledge stock	0.234*
	(0.104)
Client knowledge stock	-0.050
	(0.094)
R&D alliance experience	0.089
	(0.104)
Client alliance experience	-0.087
	(0.108)
Contract complexity	0.435***
	(0.102)
Incentives	-0.593*
	(0.299)
Prior ties	0.095
	(0.106)
Biotech-biotech deal	-0.037
	(0.253)
International deal	0.269
	(0.166)
Phase fixed effects (χ^2)	6.46
Therapy fixed effects (χ^2)	23.99***
Technology fixed effects (χ^2)	13.64
Year fixed effects (χ^2)	33.80**
Log likelihood	-155.866
χ^2	227.688***

N=350. *** p<0.001, ** p<0.01, * p<0.05, + p<0.10. Robust standard errors in parentheses.

Table 3: Determinants of cross-citations by client firms within the scope of the alliance

Variables	(1)	(2)	(3)	(4)	(5)
Steering comm. X Tech. overlap			-0.653*		-0.026
			(0.333)		(0.383)
Steering comm. X R&D know. value (in scope)				-2.820***	-2.805***
				(0.705)	(0.780)
Steering comm.		0.952*	1.096*	2.178***	2.179***
		(0.445)	(0.453)	(0.469)	(0.466)
Tech. overlap	0.450*	0.562*	0.904***	0.367+	0.384
	(0.214)	(0.234)	(0.242)	(0.218)	(0.292)
R&D firm knowledge value (in scope)	1.391***	1.389***	1.393***	3.453***	3.442***
	(0.338)	(0.322)	(0.315)	(0.637)	(0.676)
Client firm knowledge value	2.310***	2.043***	2.061***	2.328***	2.327***
	(0.426)	(0.438)	(0.460)	(0.467)	(0.464)
Knowledge concentration of R&D firm	0.382	0.462+	0.509*	0.663*	0.664*
	(0.239)	(0.249)	(0.243)	(0.274)	(0.269)
Knowledge concentration of client firm	0.355	0.025	0.040	-0.285	-0.283
	(0.272)	(0.336)	(0.340)	(0.362)	(0.367)
Alliance experience of R&D firm	-0.163	-0.130	-0.089	0.162	0.163
	(0.230)	(0.248)	(0.242)	(0.300)	(0.299)
Alliance experience of client firm	-0.323	-0.253	-0.277	-0.164	-0.165
	(0.288)	(0.288)	(0.287)	(0.313)	(0.318)
Pre-alliance citations by client firm	0.658*	0.648*	0.640*	0.697*	0.697*
	(0.273)	(0.291)	(0.279)	(0.281)	(0.282)
Deal size	-1.281***	-1.205***	-1.182***	-1.266***	-1.265***
	(0.274)	(0.285)	(0.283)	(0.319)	(0.317)
Contract complexity	1.050***	0.896***	0.952***	0.949***	0.951***
	(0.232)	(0.252)	(0.257)	(0.255)	(0.257)
Incentives	0.443	0.301	0.318	0.241	0.241
	(0.511)	(0.563)	(0.574)	(0.570)	(0.572)
Prior ties	0.308	0.505*	0.389	0.292	0.289
	(0.263)	(0.255)	(0.261)	(0.269)	(0.292)
International deal	-0.235	-0.082	-0.051	0.313	0.313
	(0.603)	(0.595)	(0.591)	(0.559)	(0.560)
Biotech-biotech deal	-0.997	-0.841	-0.811	0.159	0.155
	(0.621)	(0.617)	(0.621)	(0.645)	(0.659)
Phase fixed effects (χ^2)	28.16***	27.40***	30.94***	33.99***	32.59***
Period fixed effects (χ^2)	7.29*	9.94**	8.78*	9.49**	9.23***
Constant	-2.150***	-2.617***	-2.880***	-4.438***	-4.440***
	(0.634)	(0.703)	(0.694)	(0.706)	(0.700)
Log likelihood	-478.889	-475.353	-473.632	-461.789	-461.786
χ^2	115.571	202.442	193.174	206.340	213.172
α (dispersion parameter)	6.600***	6.416***	6.361***	5.605***	5.607***

N=350. *** p<0.001, ** p<0.01, * p<0.05, + p<0.10. Robust standard errors in parentheses.

Table 4: Determinants of cross-citations by R&D firms within the scope of the alliance

Variables	(1)	(2)	(3)	(4)	(5)
Steering comm. X Tech. overlap			-0.459		-0.209
			(0.485)		(0.496)
Steering comm. X Client know. Value (in scope)				-1.254^{+}	-1.072
				(0.756)	(0.723)
Steering comm.		0.595^{+}	0.778^{+}	1.397*	1.370*
		(0.344)	(0.415)	(0.629)	(0.628)
Technology overlap	-0.058	0.049	0.366	0.108	0.250
	(0.305)	(0.249)	(0.324)	(0.227)	(0.352)
Client firm knowledge value (in scope)	2.088***	1.994***	1.895***	2.755***	2.596***
	(0.438)	(0.406)	(0.379)	(0.664)	(0.545)
R&D firm knowledge value	2.296***	2.235***	2.245***	2.220***	2.220***
	(0.559)	(0.514)	(0.502)	(0.491)	(0.486)
Knowledge concentration of R&D firm	0.542*	0.594**	0.604**	0.664*	0.656*
	(0.222)	(0.222)	(0.233)	(0.264)	(0.257)
Knowledge concentration of client firm	-1.440*	-1.524*	-1.620*	-1.297^{+}	-1.365*
	(0.723)	(0.717)	(0.742)	(0.675)	(0.694)
Alliance experience of R&D firm	0.541	0.635^{+}	0.633^{+}	0.619^{+}	0.618^{+}
	(0.341)	(0.335)	(0.328)	(0.349)	(0.343)
Alliance experience of client firm	0.090	0.191	0.157	0.171	0.158
	(0.233)	(0.251)	(0.257)	(0.247)	(0.255)
Pre alliance citations by R&D firm	0.481	0.443	0.471	0.447	0.457
	(0.413)	(0.383)	(0.407)	(0.403)	(0.414)
Deal size	0.002	-0.043	0.070	0.071	0.107
	(0.326)	(0.318)	(0.304)	(0.295)	(0.307)
Contract complexity	0.428*	0.402^{+}	0.350*	0.284	0.278
	(0.207)	(0.212)	(0.178)	(0.191)	(0.184)
Incentives	-1.063^{+}	-1.018	-1.201	-0.999	-1.083
	(0.618)	(0.631)	(0.730)	(0.637)	(0.719)
Prior ties	-0.866*	-0.854*	-0.832*	-0.847*	-0.837*
	(0.425)	(0.401)	(0.389)	(0.394)	(0.391)
International deal	0.781*	0.780*	0.866*	0.741^{+}	0.785*
	(0.377)	(0.382)	(0.366)	(0.392)	(0.378)
Biotech-biotech deal	0.465	0.531	0.497	-0.041	0.029
	(1.165)	(1.060)	(0.993)	(0.807)	(0.822)
Phase fixed effects	53.16***	49.60***	54.11***	52.30***	54.40***
Period fixed effects (χ^2)	7.36*	8.16*	7.73*	7.24*	6.82*
Constant	-1.819***	-2.169***	-2.244***	-2.464***	-2.453***
	(0.575)	(0.612)	(0.553)	(0.577)	(0.566)
Log likelihood	-467.102	-465.794	-464.852	-463.846	-463.696
χ^2	216.180	229.766	246.055	254.905	265.601
α (dispersion parameter)	5.670***	5.596***	5.549***	5.581***	5.558***

N=350. *** p<0.001, ** p<0.01, * p<0.05, + p<0.10. Robust standard errors in parentheses.

Figure 1: Effect of interaction between steering committees and technology overlap on cross patent citations by client firm in technology areas within the scope of the alliance

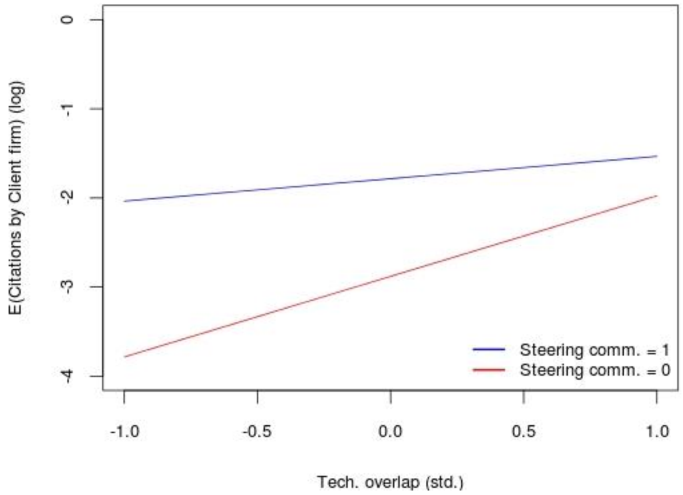

Figure 2: Effect of interaction between steering committees and R&D knowledge value on cross patent citations by client firm in technology areas within the scope of the alliance

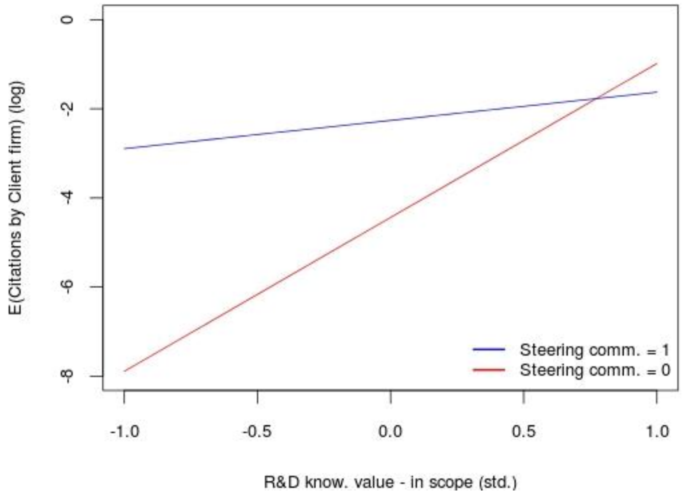

Figure 3: Effect of interaction between steering committees and client knowledge value on cross patent citations by R&D firm in technology areas within the scope of the alliance